Potential Reductions in GHG Emissions from Selected Industries in California

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Presentation Overview

- Big Picture of CA GHG Emissions
- CA Cement Production (CO_2)
- CA Petroleum Refining (CO_2)
- CA Dairy Farms (CH_4)
- Policy Options and Issues for CA Industrial Sector
- Conclusions

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Cement Production Overview

- Raw materials are ground and blended and then fed to a long (200–500 feet), slowly rotating cement kiln.
  - 77% limestone ($CaCO_3$), 11% cement kiln dust (CKD), 6% aluminous, 5% siliceous, 1% ferrous
- Raw materials are converted to clinker in the kiln at ~2700°F.
  - 1.7 metric ton of raw material per 1 metric ton of clinker
  - Fuels (US): 74% coal, 16% pet. coke, 4.2% natural gas, 3.6% tires
  - CO_2 from fuels and calcination ($CaCO_3 \Rightarrow CaO + CO_2\uparrow$)
- Clinker is then cooled for subsequent cement production.
- Typically, clinker (~95%) and gypsum (~5%) are ground together in the finish mill to make (portland) cement.
- Clinker/cement chemistry is very important to cement performance, which sets operational limits.

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CA Cement Production Overview

- 11 cement facilities in CA: 3 North (3 kilns); 8 South (17 kilns)
- All 20 kilns use dry processes (less energy-intensive than wet).
- ~4 $MMTCO_2$ from fuel in 2003 (CCAP)
- ~6 $MMTCO_2$ from calcination in 2003 (CCAP)
- ~42 TBtu consumed for CA clinker in 2003 (CCAP)
  - 1.3 million tons coal (31 TBtu) (actual 2003)
  - 220,000 tons pet. coke (5.4 TBtu) (actual 2003)
  - 4.5 million tires (~1.2 TBtu) (actual 2001; latest)
- ~1,700 GWh consumed for clinker/cement in 2003 (CCAP)
  - 175 GWh self-generated from waste heat (actual 2003)
  - ~0.7 $MMTCO_2$ from average grid electricity (est. 2003; electricity CO_2)

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Key Assumptions in CA Cement Analysis

- Clinker/cement baselines projected from recent CA data (USGS)
- Fuel/electricity consumption from comparable US data with some adjustments for CA (e.g., tires, natural gas, and electricity)
- Clinker and cement production after 2005 increasingly efficient
- EE measures applied individually at total technical potential in 2005 at 2005 capacity and production for energy savings during 2006-2025
  - Energy and CO_2-emission reductions not additive collectively
  - Likely maximizes CO_2-emission reductions and financial results
- Reductions in fuel consumption taken from all fuel sources (ex. tires)
- Reductions in electricity usage taken from purchased grid electricity
- Financial benefits only from lower operating costs (if any) and lower fuel and electricity costs from 2006-2025 (e.g., no NO_x emission credits)
- Cash flows in 2003$ discounted back to 2005 at 7% annually

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EE Measures Considered for CA Cement

- 23 EE Measures for raw material, kiln, finishing, general operations, and product change using existing technologies, not emerging ones
- Raw Material (4): More-efficient transport; grinding, blending
- Kiln (9): Reduced heat losses, greater heat recovery for reuse and power generation, and fuel switching from coal (i.e., waste tires)
- Finishing (4): More-efficient grinding and blending
- General (4): Greater preventative maintenance and process control, more-efficient motors and drives
- Product Change (2): Reduction of clinker content of cement to 65% (blended cement) and improvement in clinker formation with steel slag (CemStar™), both with associated emissions reductions (e.g., NO_x)

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Major Data Issues and Uncertainties in CA Cement Analysis

- Operating data for CA cement plants not plentiful
- Different sources of data inconsistent (e.g., USGS vs. CEC)
- Use of US averages not necessarily valid for CA
- Downtimes required for implementing EE measures uncertain
- Potential significant changes in cement industry within 20 years
    - Future cement performance standards likely to favor blended cement
    - Expiration of CemStar^{TM} license expected around 2014 with uncertain industry reaction
- Costs of blended cement and CemStar^{TM} <u>in CA</u> uncertain
- Emergence of advanced clinker/cement technologies
- Future fuel and electricity prices uncertain

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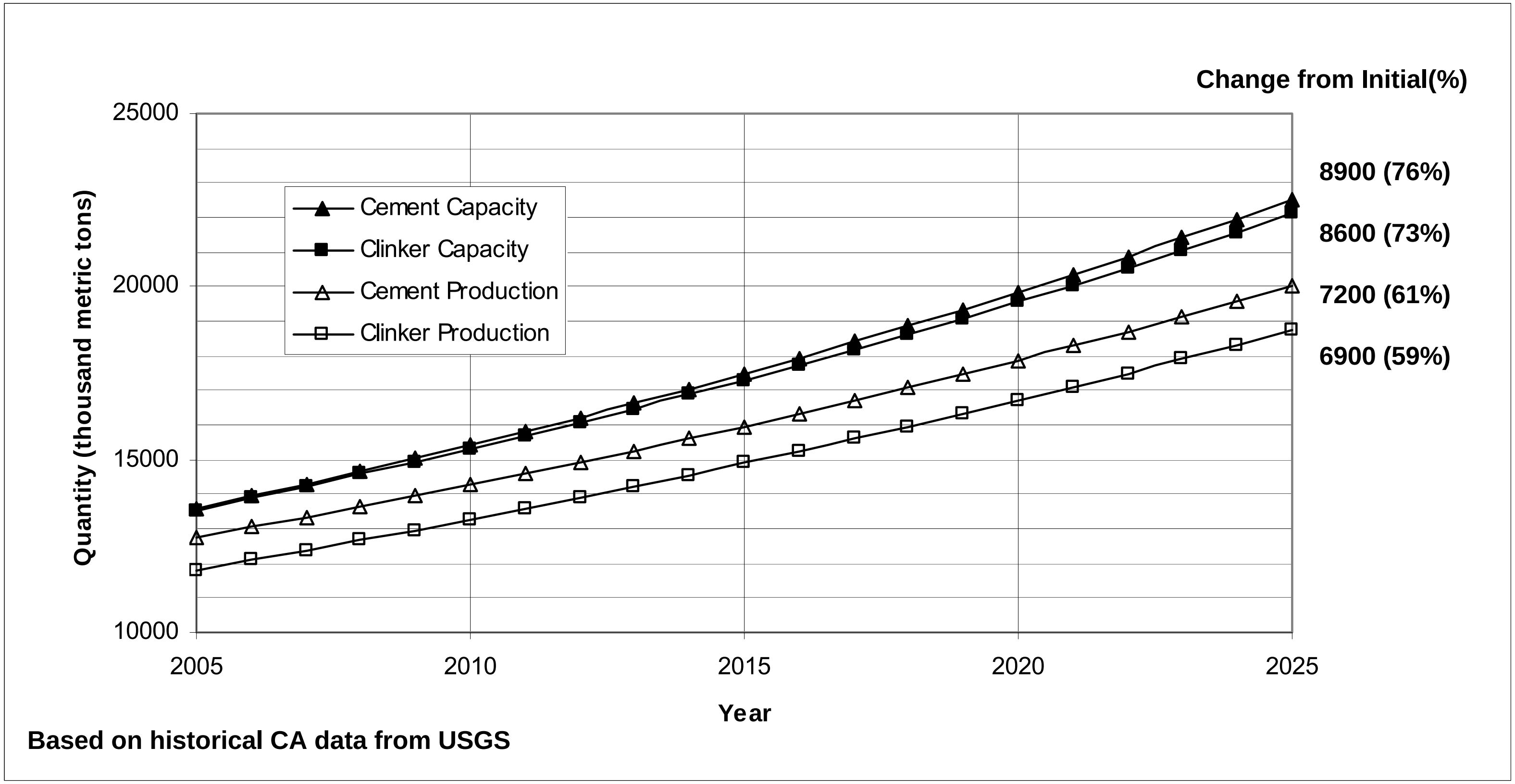
CA Clinker and Cement Baselines



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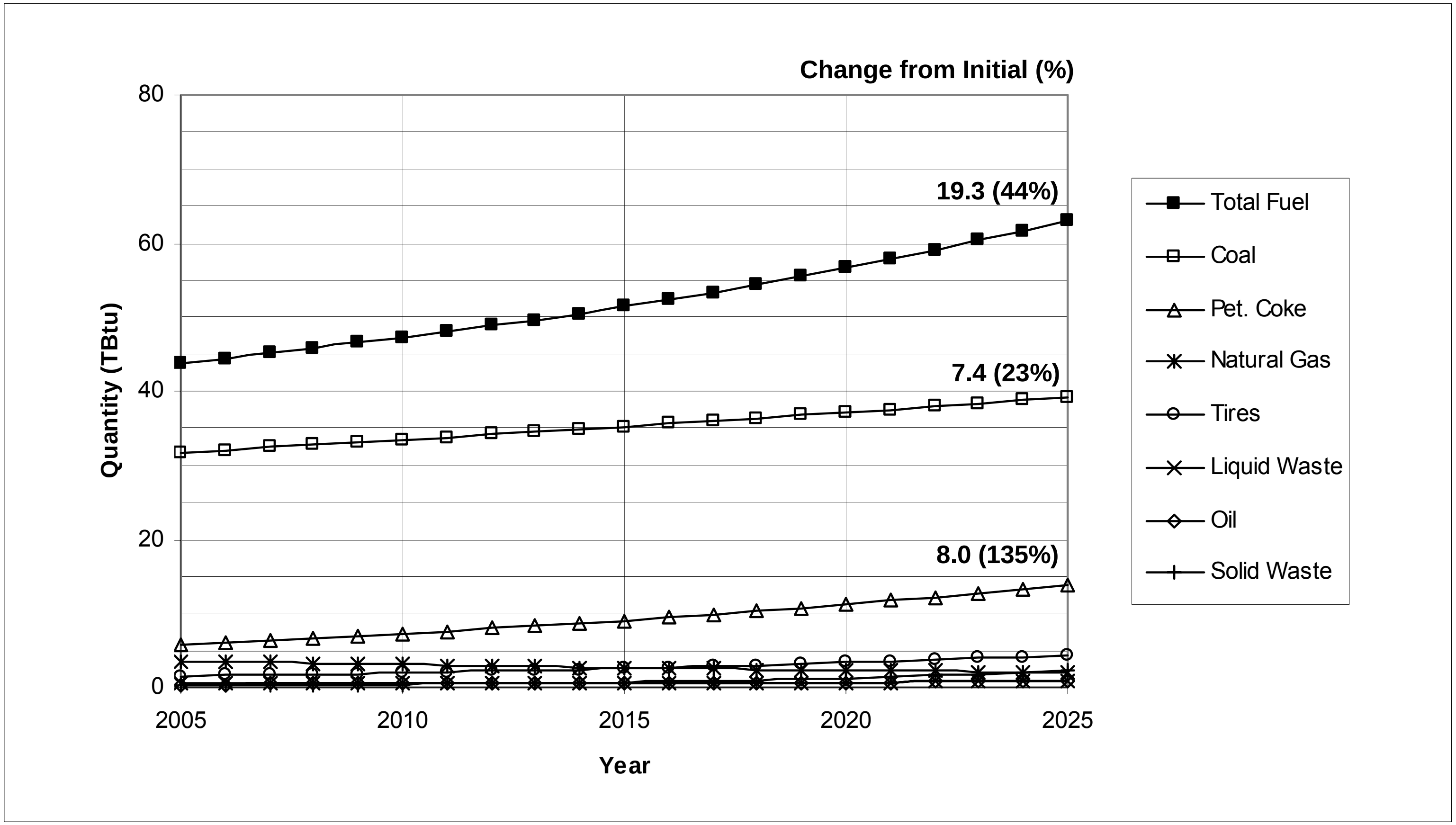
Baseline Fuel Consumption in CA Clinker Production



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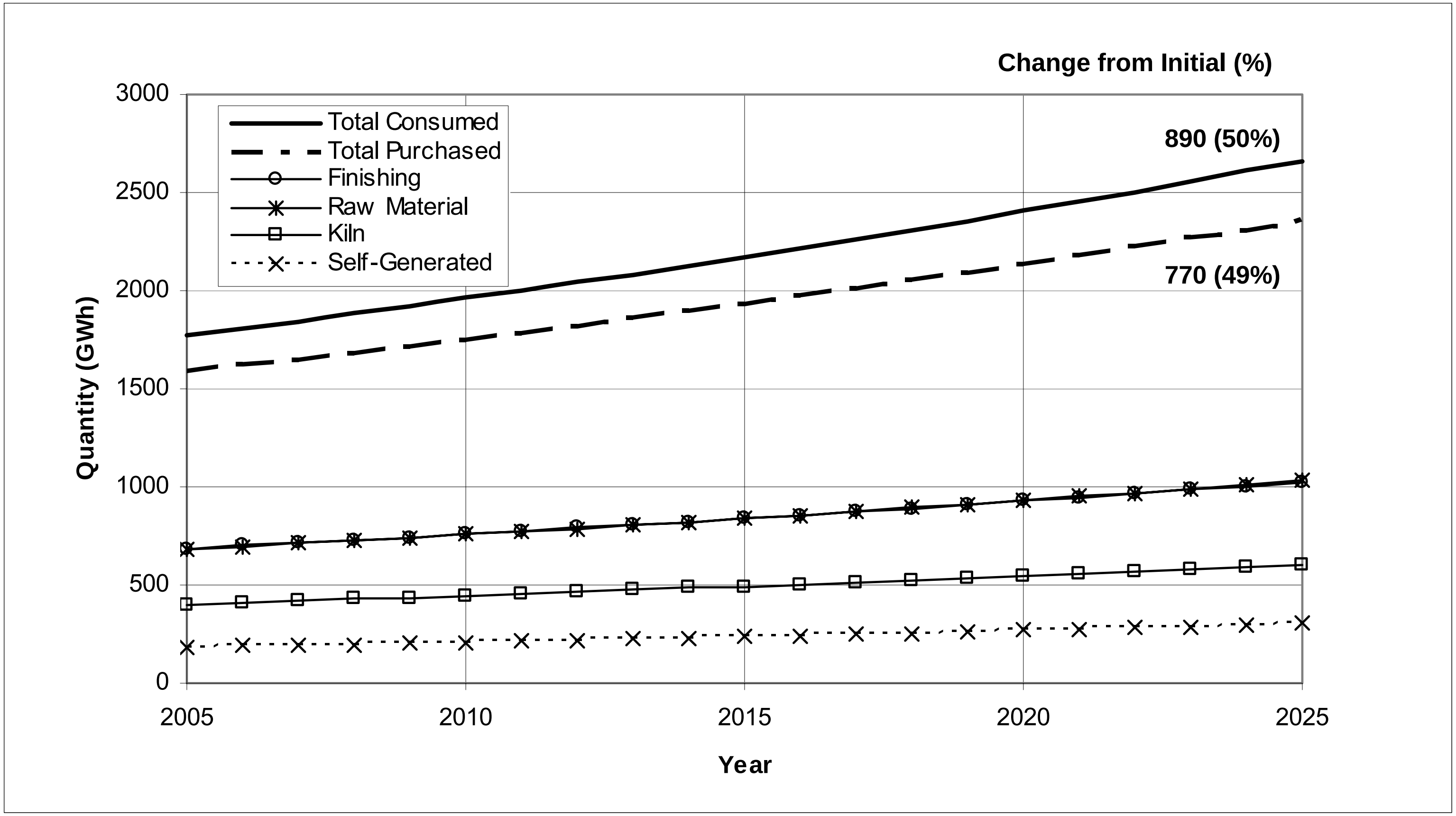
Baseline Electricity Consumption in CA Cement Production



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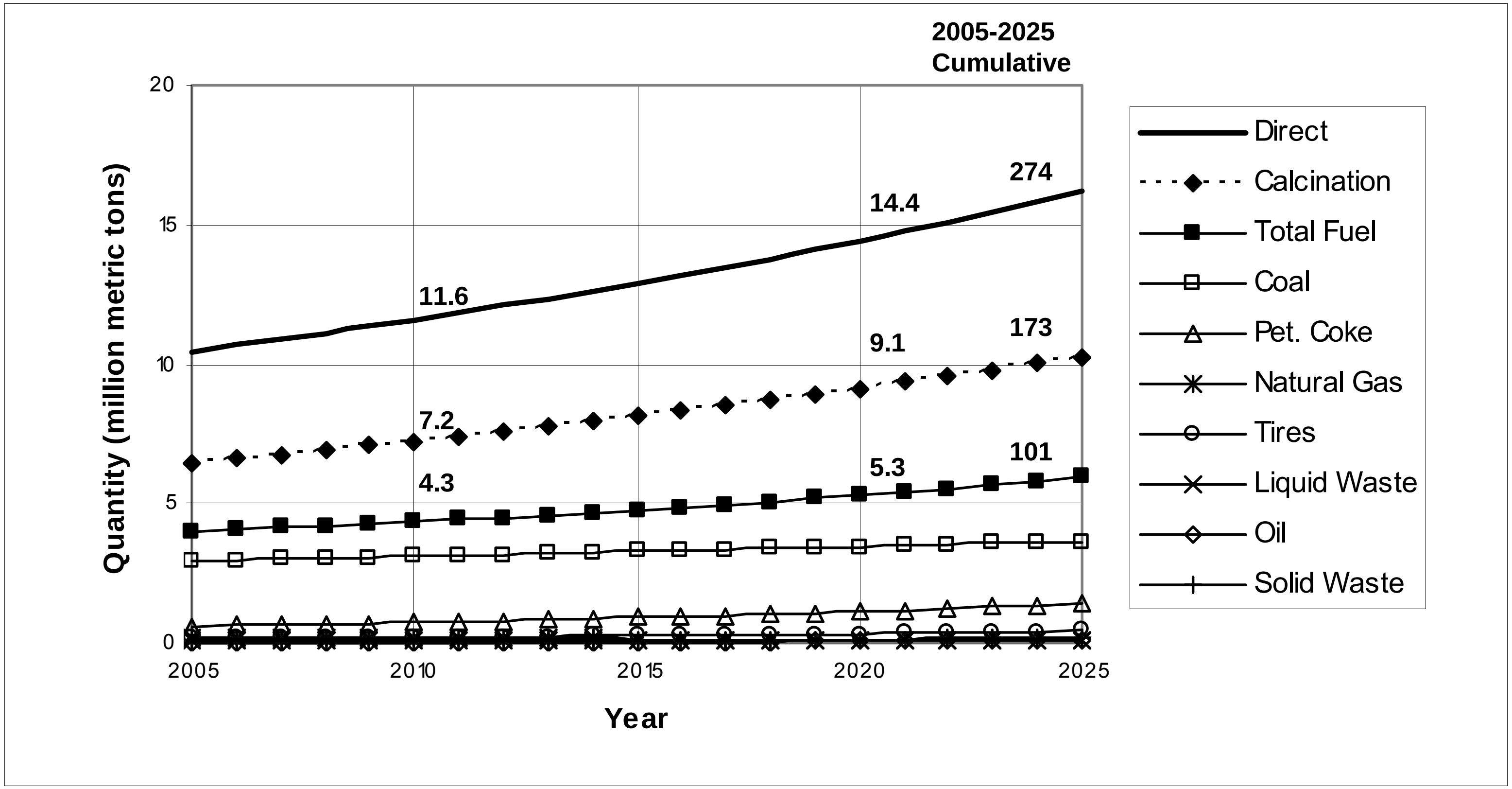
Baseline Direct (Fuel + Calcination) CO_2 Emissions from CA Clinker Production



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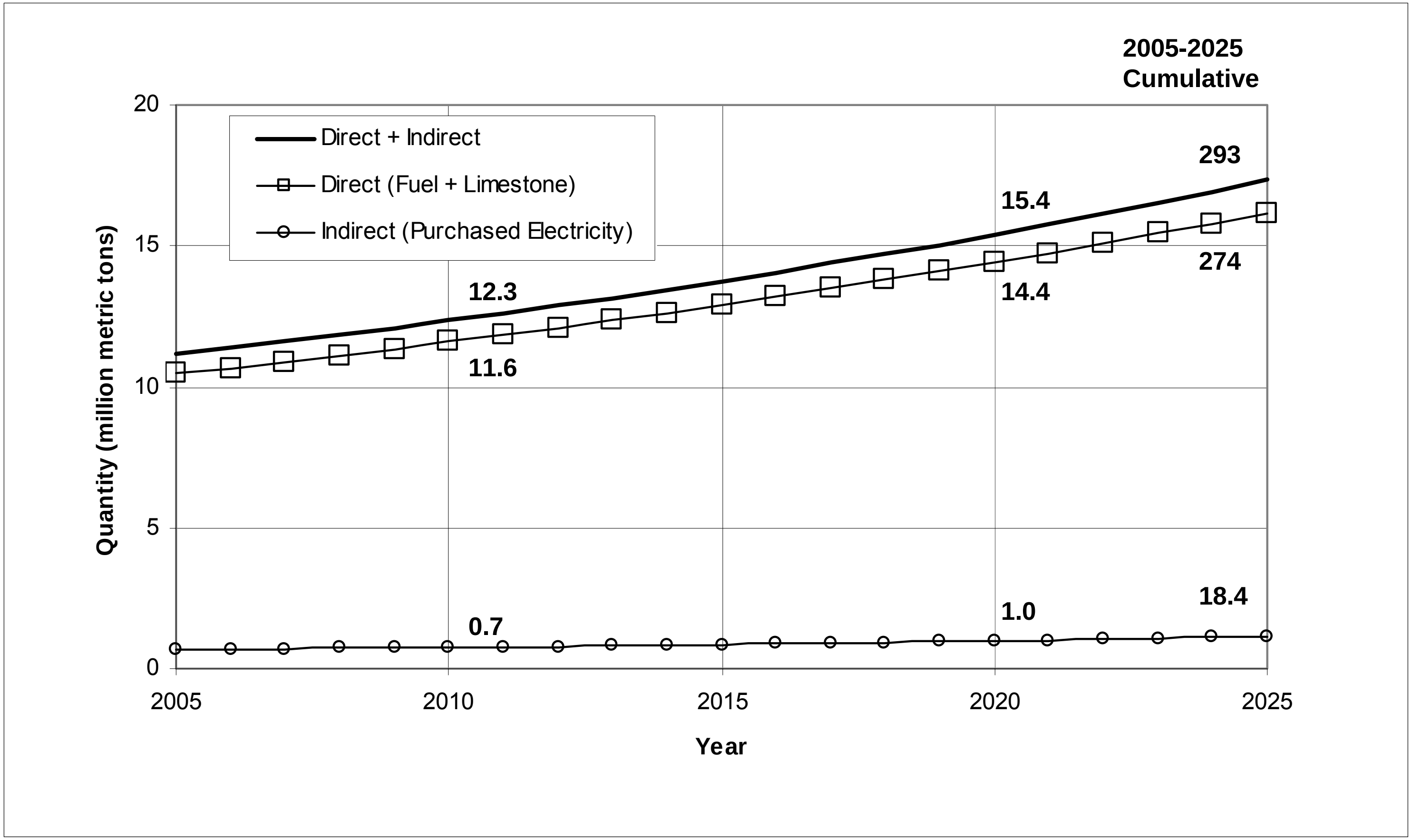
Baseline Direct + Indirect CO_2 Emissions from CA Cement Production



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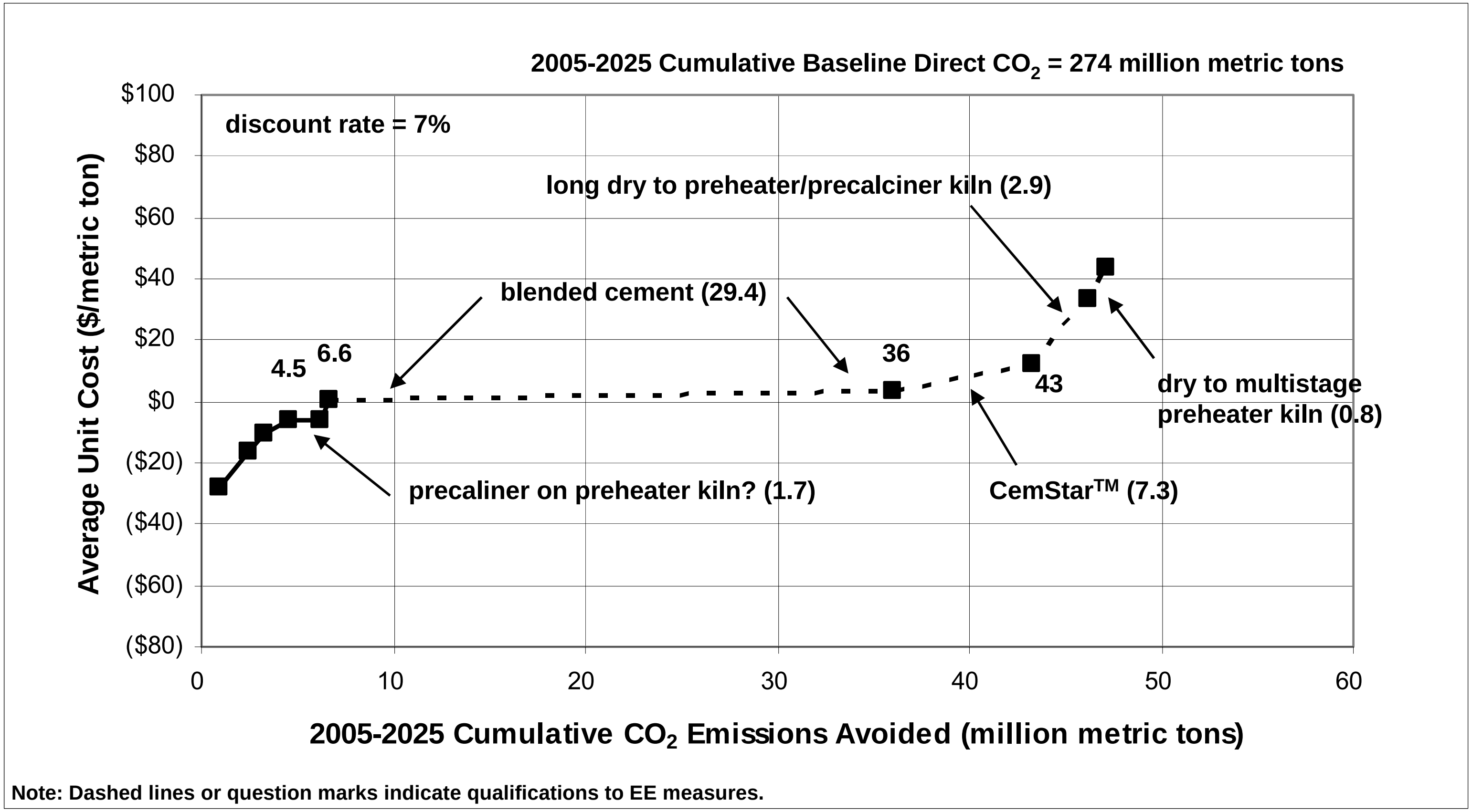
Abatement Curve for 2005–2025 Cumulative Direct CO_2 Emissions



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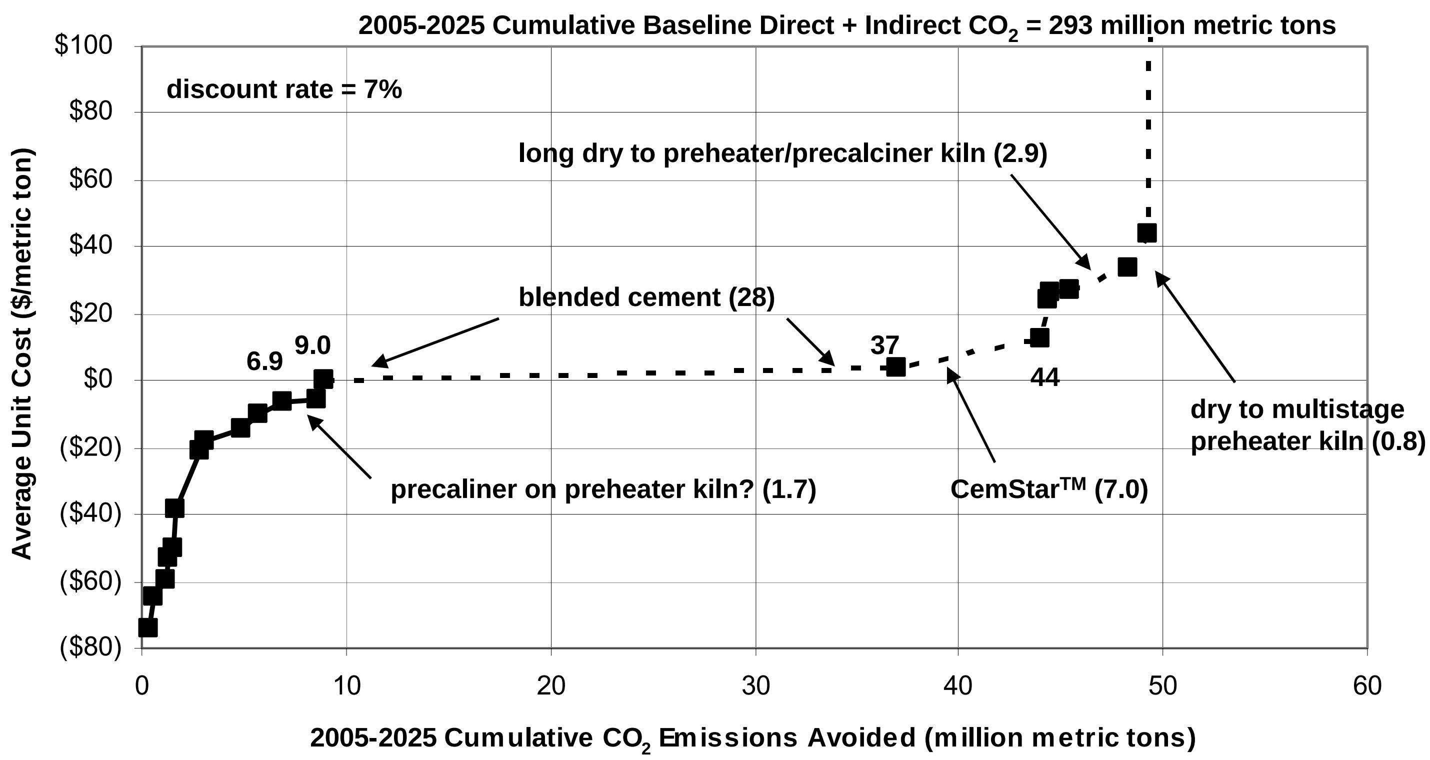
Abatement Curve for 2005–2025 Cumulative Direct + Indirect CO_2 Emissions



Note: Dashed lines or question marks indicate qualifications to EE measures.

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Synopsis of Abatement Costs and 2005–2025 Cumulative CO_2 Emissions Reductions of EE Measures

EE Measure (#)	2005–2025 Direct CO_2 (MMT)	2005–2025 Indirect CO_2 (MMT)	Payback (y)
Raw Material (4 of 4)	0	<1.0	No payback
General (4 of 4)	0.9–1.6	0.2–0.3	<4
Finishing (4 of 4)	0.1–0.7	0	3–13
Kiln (4 of 9)	0.8–1.7	<0.2	1–14
Product Change (2 of 2)	*7.3–29.4*	*(0.3) –(1.4)*	*No payback*
Waste Tires (Kiln)	(0.14)	0	1.5

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Conclusions about Potential CO_2 Emissions Reductions from CA Cement

- Cumulative reductions in CO_2 emissions are unlikely to exceed 50 $MMTCO_2$ from 2005–2025, out of 274 $MMTCO_2$ of direct emissions from cement production.
- Cumulative reductions of ~6 $MMTCO_2$ of direct emissions from 2005–2025 possible at net savings (2.3% reduction)
- Blended cement and CemStar™ account respectively for ~30 and ~7 of the 50 $MMTCO_2$ in maximum cumulative reductions at estimated abatement costs of ~$4 and ~$13 per metric ton; however, their feasibility and overall costs are uncertain.
- Measures costing more than CemStar™ (>$24/metric ton) appear unlikely to provide large additional reductions in CO_2 emissions.

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Implementation Issues for EE Measures in CA Cement

- Large capital costs without downtime
  - e.g., roller mills: $96M; high efficiency classifiers, $35M (aggregate)
- Large capital costs, downtimes, and downtime opportunity costs
  - e.g., preheater/precalciner kiln: $83M cap., 26 wk, $47M opp. (ag.)
- Waste Tires (3 of 6 permitted CA plants burning tires)
  - Public opposition
  - Likely increased CO_2 emissions from kilns
- Blended Cement
  - Current cement standards impeding its wider production
  - Sufficient economic fly ash or steel slag available in CA?
- CemStar^{TM}
  - High license fee to disappear around 2014 with patent expiration
  - Sufficient economic steel slag available in CA?

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Potential Next Steps for CA Cement Analysis

- Consult CA cement industry for better data and projections on CA clinker and cement operations, especially with regard to feasibility of EE measures
- Find and obtain obscure or unpublished data on fuel and electricity consumption by CA cement facilities
- Evaluate different scenarios of phased-in implementation of EE measures
- Assess impact of future fuel and electricity prices on implementation of EE measures and their abatement costs and GHG reduction benefits

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Petroleum Refining Overview

- Crude oil is first desalted and then separated into different fractions according to boiling point by distillation.
- The different fractions are further processed (e.g., catalytic cracking, hydrocracking) to produce a wide variety of products (e.g., gasoline, diesel, jet fuel, distillate).
- Contaminants (e.g., sulfur and nitrogen) are removed and captured by dedicated processes (e.g., hydrotreating).
- Refineries use large amounts of natural gas (NG), electricity (purchased), steam (purchased) and byproduct fuels (e.g., refinery gas) for heat, steam, and cogenerated electricity.
- Refineries emit large quantities of CO_2 and other gases from fuel consumption and operations.

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CA Petroleum Refining Overview

- 14 refineries "near" SF (4) and LA (10) operated by 8 companies
- Total average daily throughput about 2 million barrels of crude
- CA refineries more energy-intensive than average US refinery because of CA product mix and CA environmental standards
- Refiners among largest industrial users of electricity and NG
- Refiners consumed ~400 TBtu of NG (purchased) and crude byproducts and ~30 TBtu of purchased electricity and steam in 2001.
- ~26 MMTCO_2 from fossil fuels by refineries in 2001 (CCAP)
- ~1300 MW of cogeneration capacity in refineries in 2003 (CEC)
- 9000 GWh in cogeneration in 2003: 60% used, 40% sold (CEC)
- Refineries sell more electricity than they purchase.
    - Refineries emit CO_2 for sold electricity, like electricity producers.

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Key Assumptions in CA Petroleum Refining Analysis

- No new refineries built in CA
- Increasing operable capacity at existing CA refineries (0.5%/y growth)
- Constant relationship between operable capacity and operating capacity (98%, stream day; 94%, calendar day)
- Rising capacity utilization to meet demand (93%; 0.25%/y growth rate)
- Energy intensity and energy consumption of CA refinery operations taken from LBNL-55450 with adjustments for H_2 production based on NREL data
  - Adjustments apparently made energy balance work, but material balance still inconsistent with NG consumption data from CEC
- Cogeneration and purchased electricity based on CEC data
- Intensity of H_2 production increases for cleaner fuels in future.

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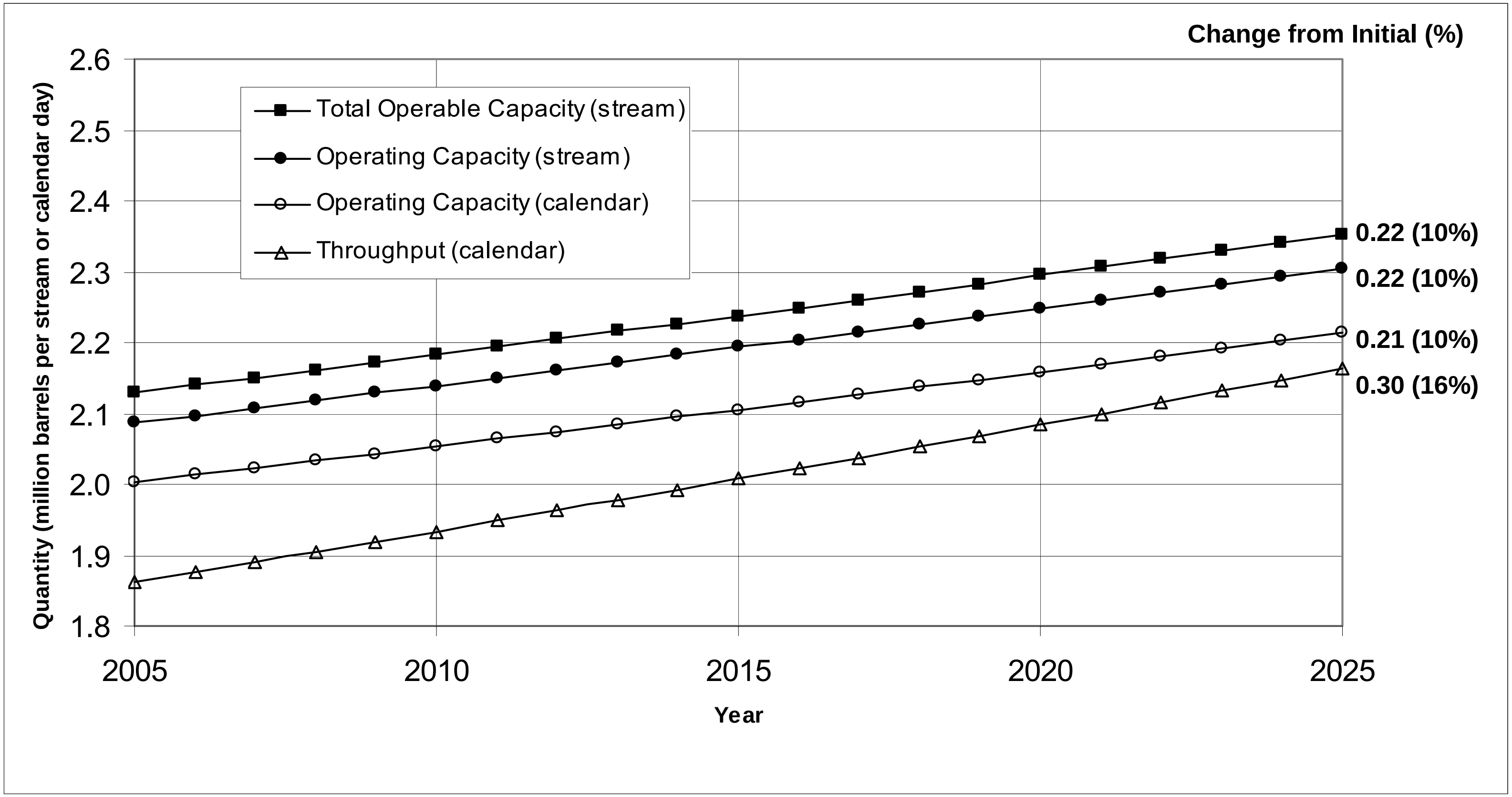
Major Data Issues and Uncertainties in CA Petroleum Refining Analysis

- "There is no publicly available data on energy consumption in refineries in California" (LBNL-55450, p 29)
- Different sources of data significantly inconsistent
  - Inferred energy and material balances apparently do not work.
- Possible undercounting of NG consumption because NG is tracked as fuel, not feedstock for H_2 production (major energy consumer in CA refineries)
  - Unrecognized process CO_2 emissions from H_2 production? (not in IPCC)
  - These process CO_2 emissions inadvertently among combustion CO_2?
- Very few publicly available data for implementation cost and energy saved of EE measures that have quick paybacks
  - Abatement costs for CA refining could not be calculated at present.
  - Only estimates of energy consumption and CO_2 emissions possible

Baseline CA Petroleum Refining Capacity and Throughput



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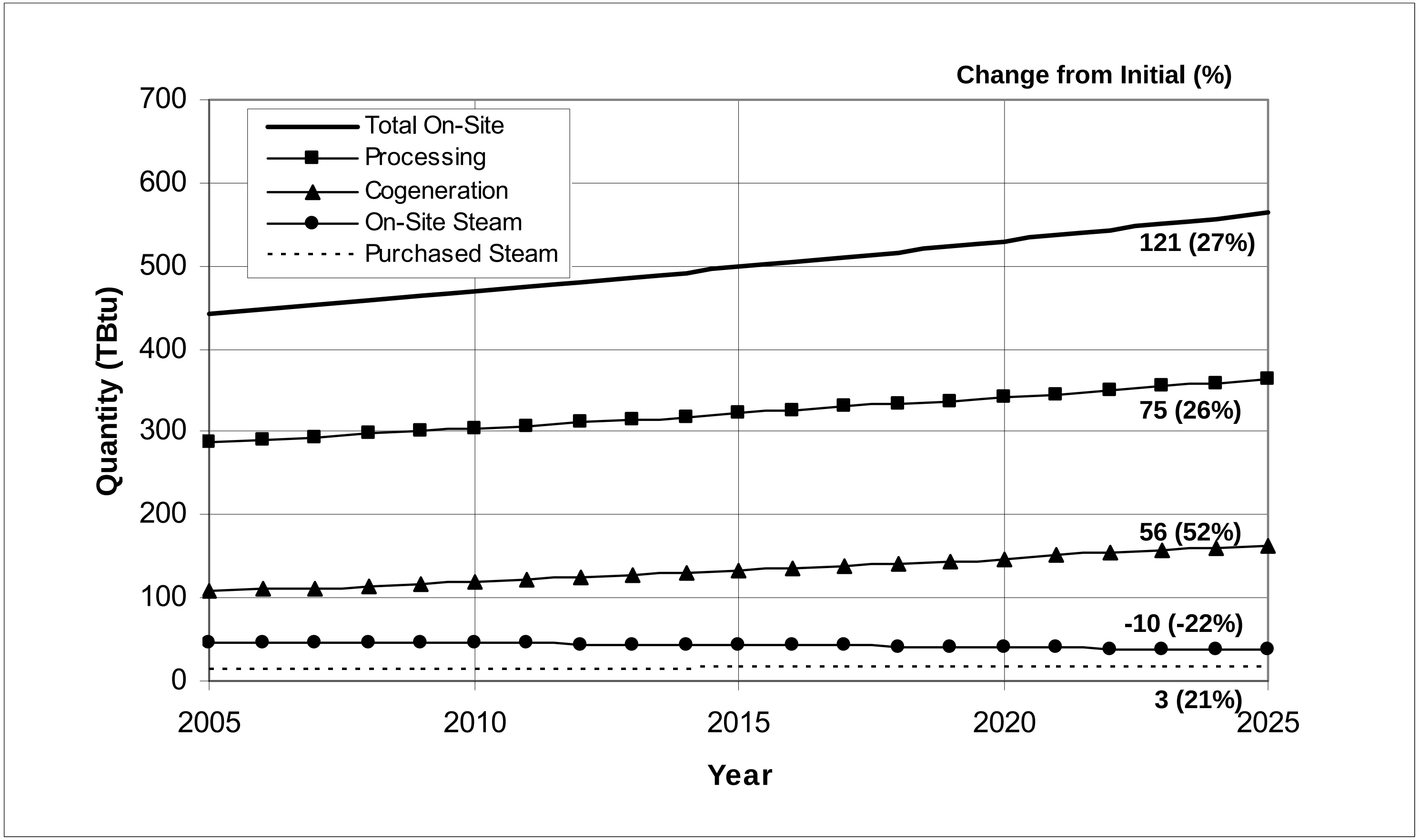
Baseline Fuel Consumption by General Use in CA Petroleum Refining



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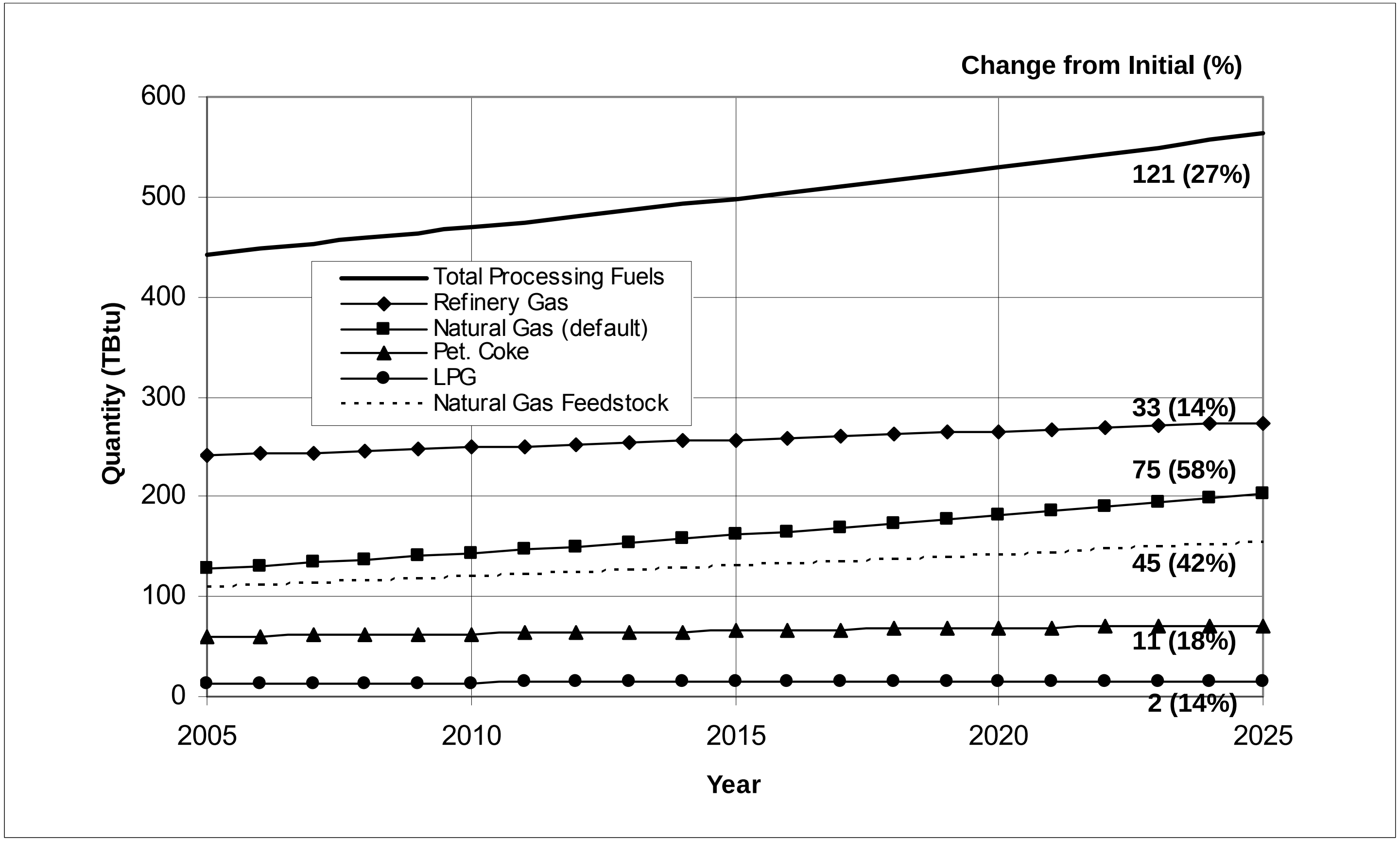
Baseline Fuel Consumption by Fuel in CA Petroleum Refining



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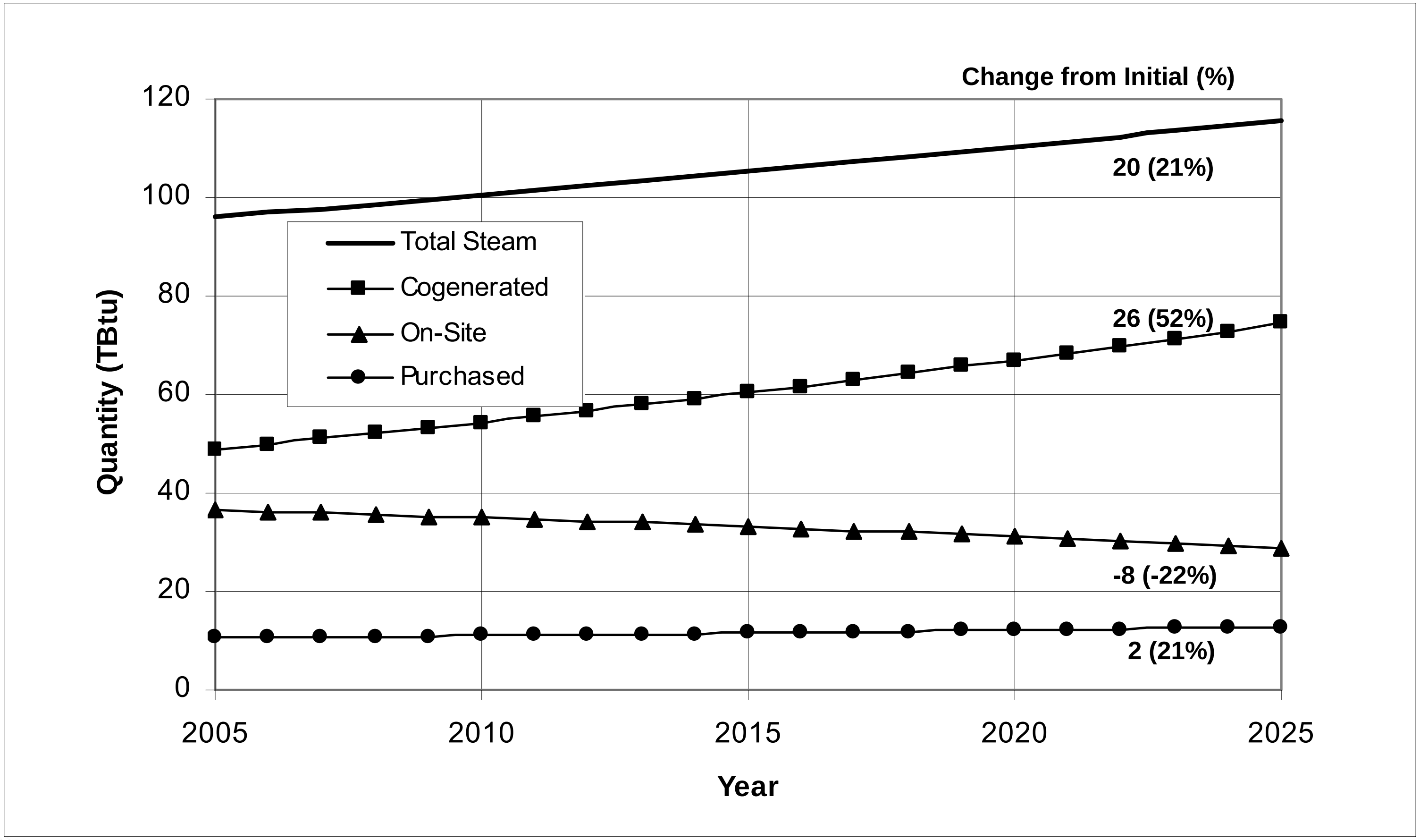
Baseline Steam Consumption by Type in CA Petroleum Refining



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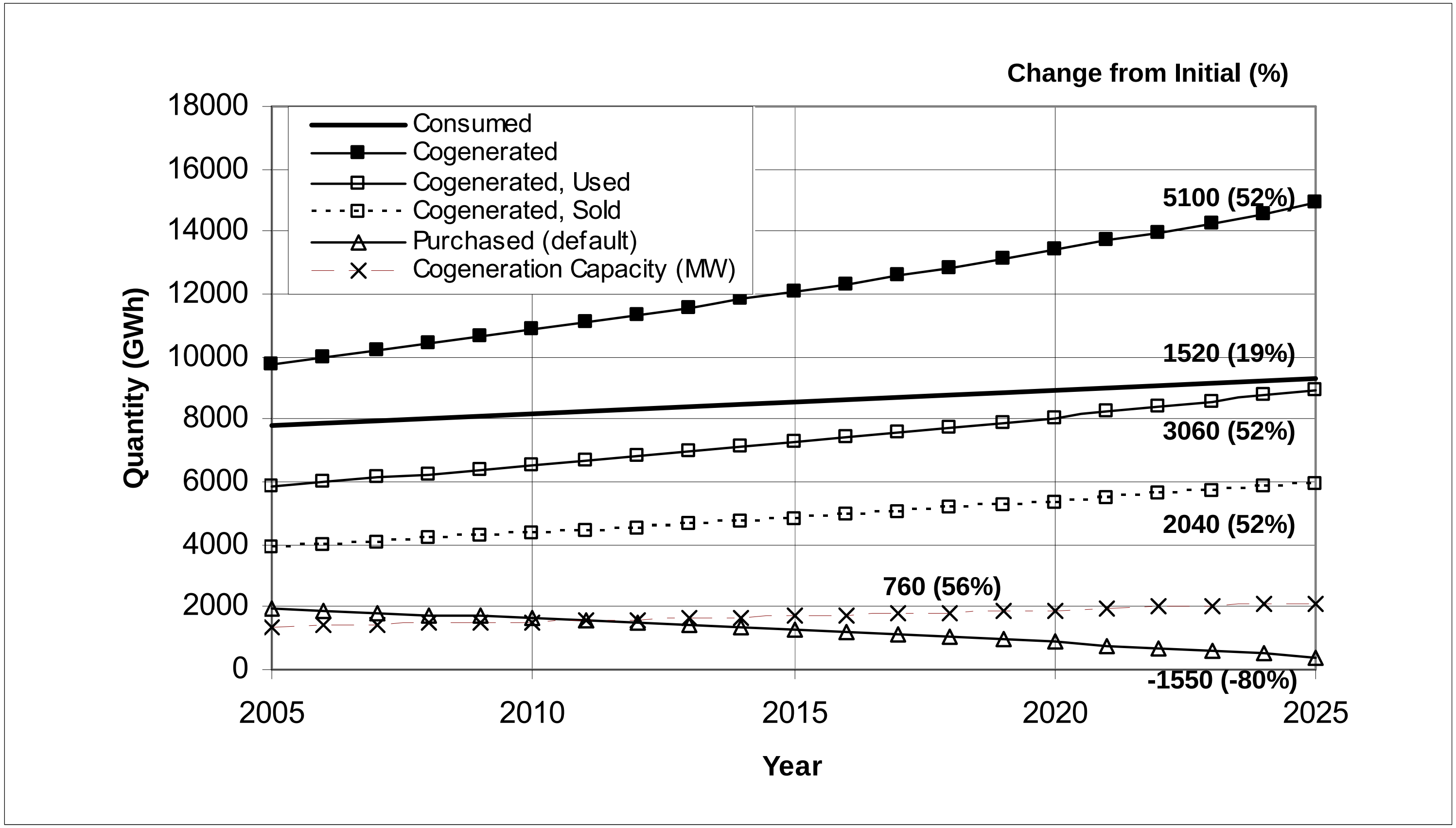
Baseline Electricity Consumption by Type in CA Petroleum Refining



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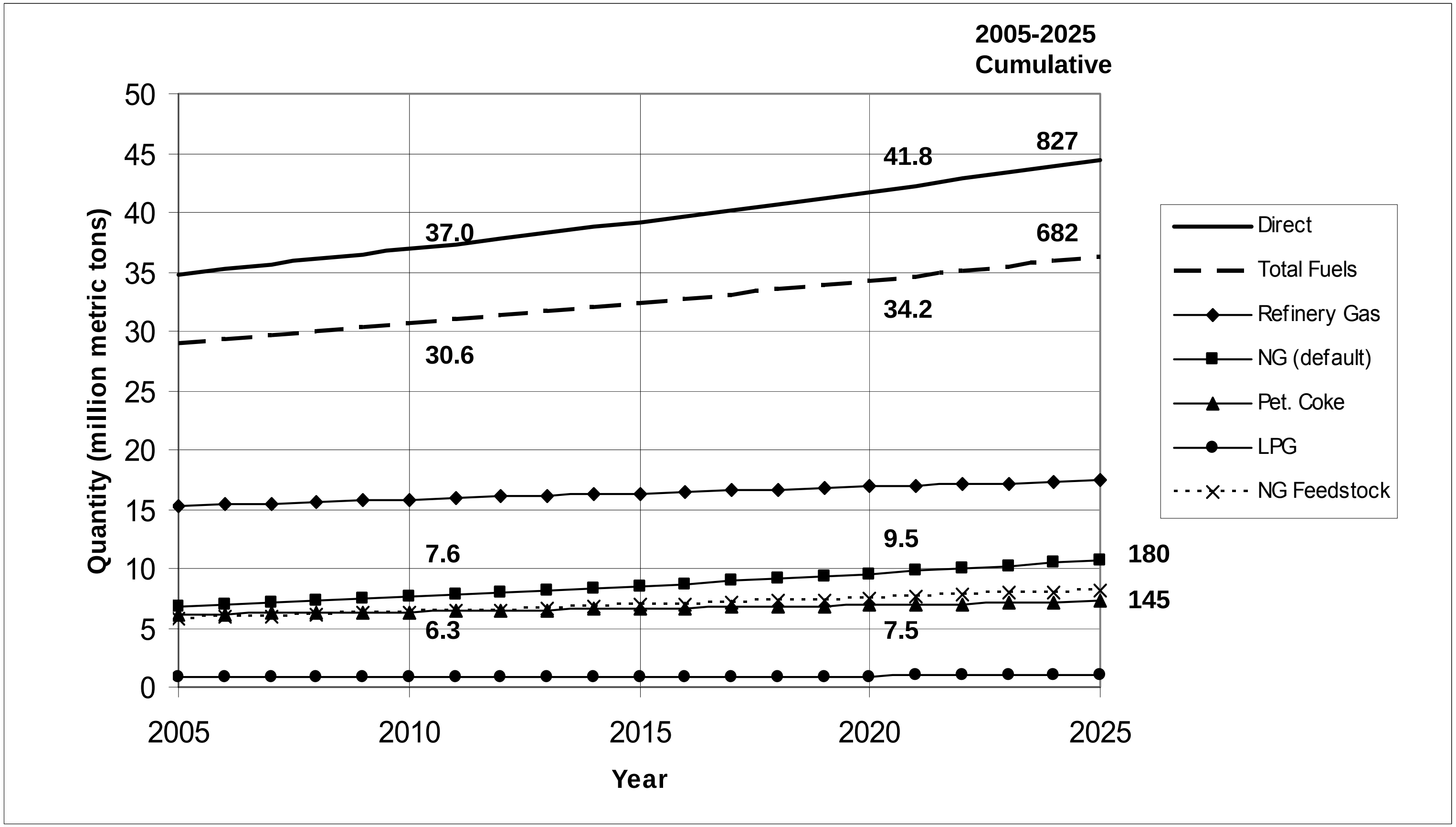
Baseline Direct (Fuel + Feedstock) CO_2 Emissions from CA Refining



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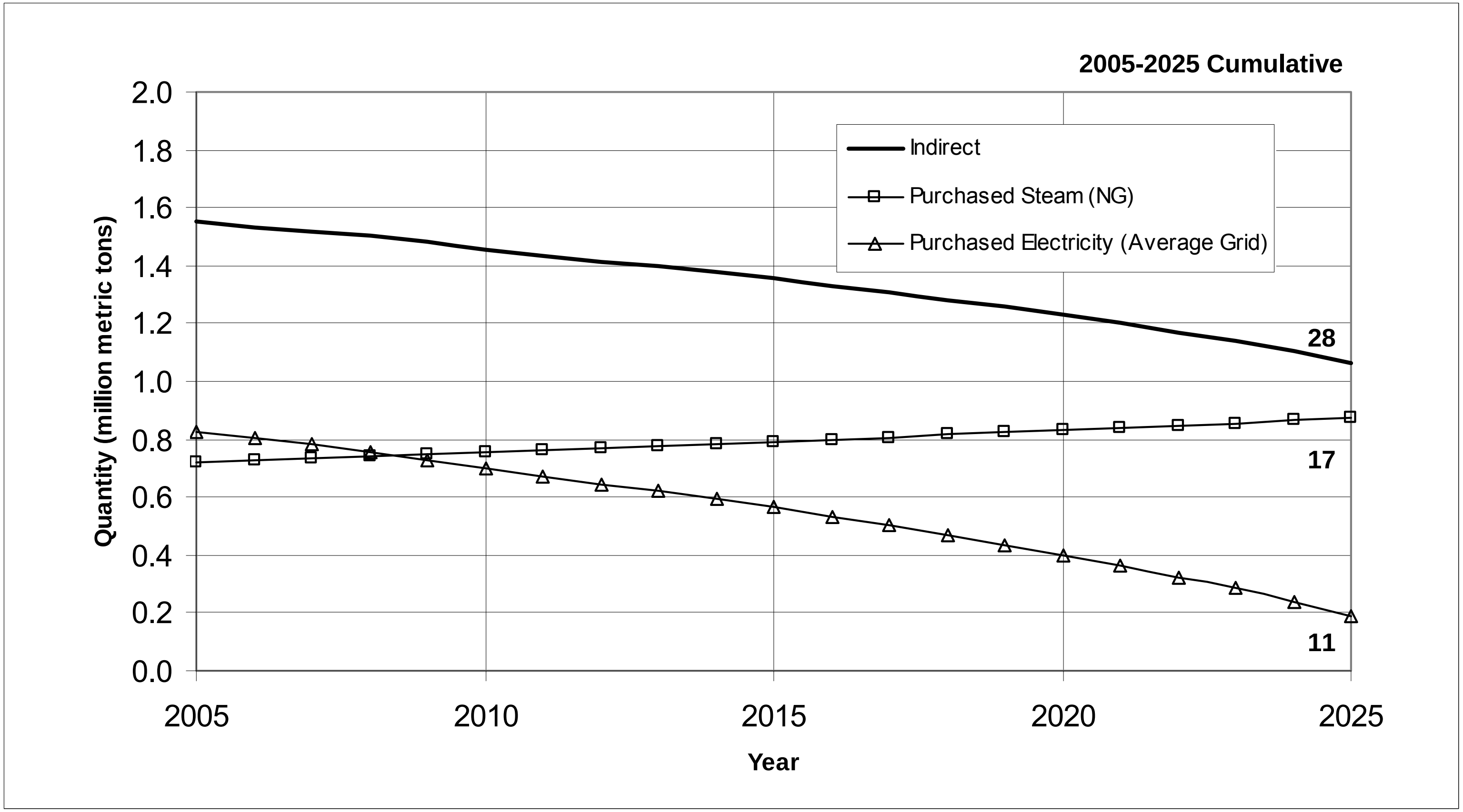
Baseline Indirect (Steam + Electricity) CO_2 Emissions from CA Refining



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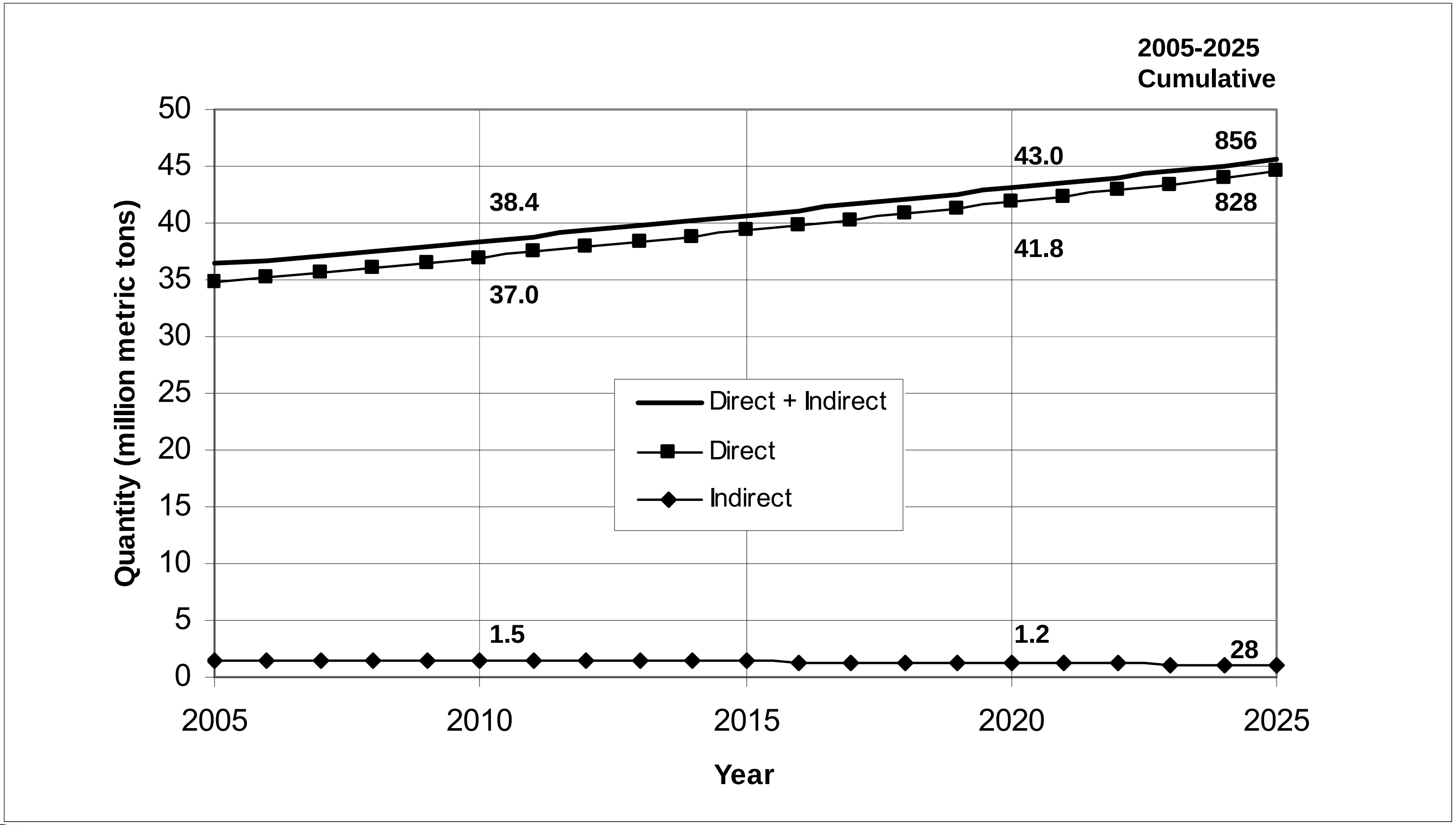
Baseline Combined (Direct + Indirect) CO_2 Emissions from CA Refining



CCAP Preliminary Estimates for CA Petroleum Refining from 2005–2025

- Daily throughput to increase 16% from 1.86 to 2.16 million barrels
- Fuel consumption to increase 27% from 443 to 564 TBtu from 2005–2025 for refining processes (+26%), steam (–22%), and cogen. (+52%)
- NG consumption to increase 58% for fuel from 128 to 203 TBtu and 42% for feedstock from 109 to 154 TBtu
- Electricity demand to increase 19% from 7800 to 9300 GWh
- Cogeneration capacity to increase 56% from ~1400 to 2100 MW
- Cogenerated electricity to increase 52% from 9800 to 14900 GWh, with purchased electricity dropping 80% from 1900 to 400 GWh
- CO_2 emissions from all fuels to increase 25% from 29 to 36 MMT
- CO_2 emissions from NG feed to increase 42% from 5.8 to 8.2 MMT
- Direct CO_2 emissions to increase 28% from 35 to 44 MMT
- Indirect CO_2 emissions to decrease 31% from 1.6 to 1 MMT

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Potential Next Steps for CA Petroleum Refining Analysis

- Consult CA petroleum industry for better data and projections on CA refining operations, particularly regarding H_2 production from natural gas
- Conduct further research on the costs and energy benefits of EE measures, in consultation with industry and EE experts
- Improve energy and material balances for CA refineries from existing and new data
- Re-evaluate GHG emissions from CA petroleum refineries
- Evaluate the potential of EE measures to reduce GHG emission from CA petroleum refineries

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CA Methane and Digester Overview

- 1999 methane emissions from manure management totaled 5.2 MMTCO_2e (1.2% of 1999 gross GHG emissions).
- Manure management represents one of the fastest-growing sources of GHG emissions in CA
  - 5.2% average annual growth from 1990 (3.3) to 1999 (5.2)
- Installation of biodigesters can recover manure methane for on-site fuel use or electricity generation, reducing GHG emissions and improving air and water quality
- CA dairy farms have a large potential for biodigester use.

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Key Assumptions
for CA Dairy Farm Analysis

- Dairy farms with at least 500 cows are candidates for digesters.
- Total number of dairy cows assumed to increase at an average annual rate of 5% through 2010, then remain constant.
- Digesters are installed at 150 dairy farms (out of a projected 1200 large farms in 2010), at a rate of 10 farms per year from 2006-2020.
- Federal production tax credit for renewable power generation is renewed through 2025 at current level. Digesters receive credit for first ten years. Farms do not receive state funding.
- 100% of farms' excess electricity generated on-site is net metered back to grid.
- Price received by farms for net-metered electricity equals price paid by farms to purchase electricity from local grid.
- GHG savings include methane reductions from manure management and CO_2 from displaced grid-generated electricity (impact of digesters on N_2O formation assumed to be zero).
- Cash flows in 2003$ discounted back to 2005 at 7% annually

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Synopsis of Results from CA Dairy Farm Analysis

- Total GHG reductions:
  - 2010: 0.4 $MMTCO_2e$
  - 2020: 1.2 $MMTCO_2e$
  - Cumulative (2006-2025): 16 $MMTCO_2e$
- Total net savings from 2006-2025: $60 million
- Net savings per metric ton GHG reduced: $3.70
- The use of digesters can therefore achieve significant GHG reductions at a net savings
- Net metering is key: without it, GHG reductions from biodigesters would likely have a positive cost.

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Next Steps for CA Dairy Farm Analysis

- There is significant potential in the state for achieving much larger reductions in methane emissions with digesters: the total methane emissions from large dairy farms are currently about 7.5 $MMTCO_2e$ annually. This is projected to increase to an estimated 9.7 $MMTCO_2e$ in 2010 and the years after.
- Next step is to examine ways to increase reductions from this sector and to encourage implementation. CCAP is currently exploring the following issues:
  - Net metering: availability and eligibility at existing farms, technology and equipment required, costs
  - Transmission requirements and constraints at existing farms
  - Potential programs and incentives for implementation
  - Monitoring and verification requirements

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Policy Options and Issues to Reduce Industrial GHG Emissions in CA

- Technology mandates for efficient equipment and processes
  - Overinvestment in “wrong” technologies?
- Cost sharing with public funds to overcome financial barriers
  - Availability of sufficient public funds?
  - Reliance on public funding an impediment to GHG reductions?
  - Dedicated “industry” taxes to create competitive disadvantage?
- Recovery of capital and opportunity costs via state tax code
  - Tax reductions to provide sufficient funds to spur implementation?
  - Reliance on tax reductions an impediment to GHG reductions?
- Negotiated voluntary agreements
- GHG Cap & Trade Program to encourage implementation
  - Development of industrial GHG baselines without policy
  - Determination of technical potential for GHG reductions by industry
  - Setting the GHG cap across industries
  - Allocating allowances for GHG emissions among industries

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Policy Issues and Options for Verifying Industrial GHG Emissions Reductions in CA

- Measuring GHG emissions
  - Output (CEMs) vs. Input (fuels and materials) . . . or both?
  - Calculating, recording, and “memorializing” GHG emissions
- Determining actual GHG emissions reductions
  - Facility baselines for future GHG emissions without policy
  - Indirect GHG emissions (double counting)?
  - Computing “true” GHG reductions relative to baseline (end effects?)
- Verification of GHG emissions reductions
  - Third party (government agency?) to vet GHG emissions reductions
  - Public record vs. confidentiality
- Enforcement
  - Defining material noncompliance
  - Identifying companies in material noncompliance
  - Punishment and penalties for material noncompliance (publicized?)

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Conclusions for CA Industrial Analysis

- GHG emissions reductions within the CA industrial sector are likely possible at net savings.
  - 0.3 $MMTCO_2$ annually from CA cement
  - 1.2 $MMTCO_2$ annually from CA dairy farms
- Additional GHG emissions reductions within the CA industrial sector are likely possible at low abatement costs
  - 1.8 $MMTCO_2$ annually from blended cement and CemStar™ in CA cement
- Significant technical and policy issues exist for implementing measures to reduce GHG emissions and verifying the GHG reductions.
- Further study and evaluation of the CA industrial sector are necessary to determine future industrial GHG emissions and the GHG reduction potential.
  - Petroleum refining, electronics, food processing, and chemicals

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Appendix

Additional slides of data and data sources

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Big Picture

- CA has world's 6th largest economy.
- Annual CA GHGs: ~430 $MMTCO_2e$ (gross) from 1990–1999
- 1999 GHGs: 363 CO_2; 32 CH_4; 24 N_2O; 10 High-GWP
- 1999 Comb. CO_2 (356): 210 Transport; 92 "Industry"; 8 Utilities
  - Newer data: 188 (+16, bunker) Transport; 66 Industry; 43 Electricity
- 1999 Proc. CO_2: 6 mostly from cement production (calcination)
- CH_4 (32): 4↓ Energy; 13↑ Agriculture; 15↓ Solid/Water Waste
- Agriculture: 7 Enteric Fermentation; 5↑ Manure Management
- GHG emissions reductions desired to mitigate climate change
  - In-state electricity largely natural-gas fueled, with relatively few opportunities for additional GHG emissions reductions
  - Potential reduction opportunities in industry and agriculture
- Look to cement, petroleum refining, and dairy farms for GHG reductions?

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Data Sources for CA Cement Analysis

- USGS publications for CA clinker/cement production/capacity and US (not CA) fuel/electricity consumption
- Unpublished data for selected fuel/electricity consumption
- *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Cement Industry* (LBNL-44182) for costs, technical potential, and fuel/electricity savings of various EE measures
- *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002* (EPA 2004) for energy, carbon, and CO_2 factors of fuels
- *Annual Energy Outlook 2005* (EIA) for projected fuel/electricity costs (2003$) and CO_2 emissions from average grid electricity
- Publicly available data for other needs (e.g., tire-derived fuel)

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Data Sources for CA Petroleum Refining Analysis

- *Profile of the Petroleum Refining Industry in California* (March 2004; LBNL-55450) for information on US and CA petroleum refining, including potential EE measures
- CEC data for refining capacity and crude intake and consumption of NG and electricity by petroleum refineries
- EIA public databases for petroleum refining capacities and energy statistics
- *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002* (EPA 2004) for energy, carbon, and CO_2 factors of fuels
- *Life Cycle Assessment of Hydrogen Production via Natural Gas Steam Reforming* (2001; NREL/TP -570-27637) for information on hydrogen production from natural gas

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Sources for Methane Emission Data for CA Dairy Farm Analysis

- USDA National Agricultural Statistics Service for historical inventory of dairy cows and distribution by farm size in CA
- *Inventory of California Greenhouse Gas Emissions and Sinks: 1990-1999* (CEC 2002) for typical animal mass and methane emissions from volatile solids factors for California
- *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002* (EPA 2004) for volatile solids production from cattle for California (US Inventory data was used when data differed from California Inventory, since former source is more recent.)
- PIER program for weighted methane conversion factor
- US EPA AgSTAR Program for information on methane conversion with biodigesters
- CARB for projected future growth rate of dairy farms

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Sources for Biodigester, Generation and Electricity Data for CA Dairy Farm Analysis

- PIER program for on-site dairy farm electricity demand in California
- Washington State University for capital and operation and maintenance (O&M) costs of typical manure digester and electric generating unit; capacity, efficiency, and capacity factor of electric generating unit
- California Energy Commission for electricity prices paid by dairy farms and net metering benefit rate
- *Annual Energy Outlook 2005* (EIA) for average CO_2 emissions rate from grid-purchased electricity in CA

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